

COSMO-SkyMed:

- System & Products
- Status
- Expandability to ORFEO

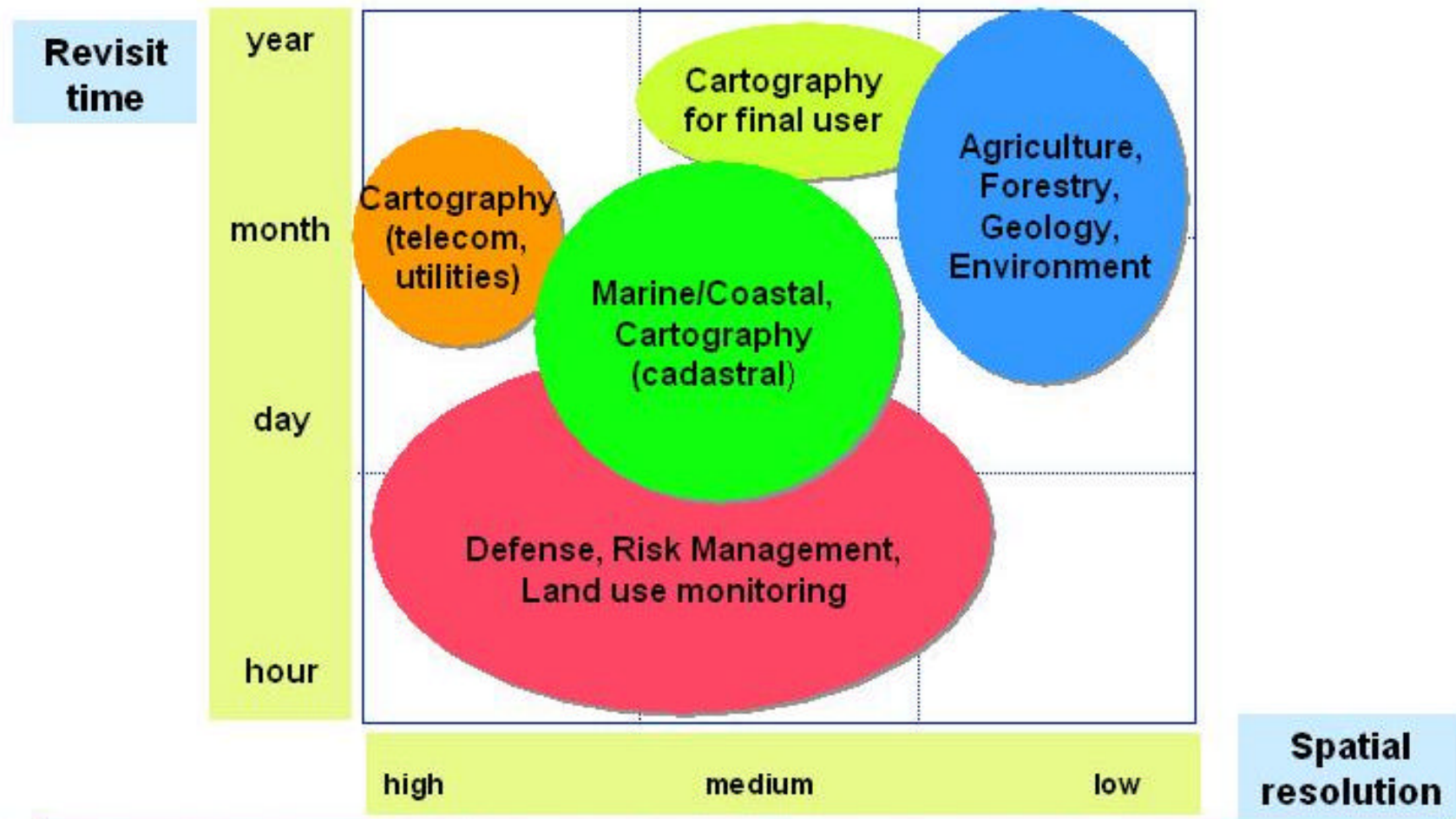
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Presented by: *Francesco Caltagirone*
ASI - UO Payload RADAR Head
COSMO-SkyMed System Manager

Why COSMO-SkyMed

- **World-wide civil protection, defense and resource managing users are under an increasing pressure to take quick and appropriate decisions on a day-by-day basis in fields like monitoring and surveillance, risk management, hydrology, forestry, environmental management, agriculture, urban planning, etc**
- **EO Market indicates that there is a strong request for products current, reliable and frequently / regularly updated**
- **EO Market is demanding higher resolution, better accuracy (geo-location, radiometry, etc.), better response/revisit time and quicker-and-easier ordering and delivery of data and products**

Application areas vs. revisit time & spatial resolution



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(Specific purpose COSMO-SkyMed).

EO Missions State of Art vs. Users and Market

User requirements are today not adequately met by operative EO missions

- Current EO missions have limitations, especially, with:
 - ✓ capability to provide data and products characterized by adequate spatial and spectral resolution, to perform analyses at different scales of detail
 - ✓ fast response time and revisit time
 - ✓ capability to acquire images day-night and in all weather conditions
 - ✓ capability to acquire, in a single pass, sufficiently large areas
 - ✓ capability to directly interface users (data sets have to be ordered through different distributors, becoming sometimes available with a long delay)

- Available multi-temporal data set are often not homogeneous neither comparable

Dual Use – Users needs

☐ Defence needs

- **Defence requests have priority**
- **Defence tasking is confidential**
- **Communication links are secure**
- **Defence products are classified**

☐ Civilian needs

- **Fulfillment of the different needs**
 - ✓ institutional users (National and International, i.e. GMES)
 - ✓ scientific users
 - ✓ commercial users
- **Open access to the system via public networks**

☐ Common needs

- **Large quantity of images to be acquired**
- **Flexibility**
 - ✓ Multi-mode operation (variety of sizes and resolutions)
 - ✓ Agility (several images on a theater)
- **High Reactivity**
 - ✓ Response / Revisit Time

COSMO-SkyMed Mission vs. Users and Market

COSMO-SkyMed has been conceived with the aim:

- to establish a reliable, all-weather, day-night, global service
- to supply services and products directly to the end users
- to satisfy most of the user applications and of the market demand

COSMO-SkyMed Mission answer to users application and to the market demand, is characterized by the following peculiar features:

✓ Dual Use (Priority and Security Management)	✓ Variable sizes (up to hundreds of Km) and resolutions (up to metric/sub-metric)
✓ Day-night-all weather capabilities	✓ Response / Revisit time of few of hours
✓ High Image Quality	✓ High agility (multiple images in a theater)
✓ Polarimetry	✓ Large number of images
✓ Interferometry	✓ Very accurate geolocation

COSMO-SkyMed Mission statement

- COSMO-SkyMed is an end-to-end Mission dedicated to Earth remote sensing and data exploitation for Dual (military and civil) Use applications.
- Main mission objective is therefore the provision of data, products and services relevant to the:
 - ✓ monitoring, surveillance and intelligence applications of MoD entities;
 - ✓ environmental monitoring, surveillance and risk management applications of institutional entities;
 - ✓ environmental resources management, maritime management, earth topographic mapping, law enforcement, informative / science applications of other institutional, scientific and commercial entities.

COSMO-SkyMed, funded by the Italian Ministry of Research and Ministry of Defence and conducted by the Italian Space Agency (ASI), appears to be the first System (and mission) capable to fully meet the requirements for monitoring, surveillance and intelligence applications and for the management, control and exploitation of Earth resources, in a coordinated manner with Optical Satellites.

COSMO – SkyMed Program Status

TODAY, THE COSMO-SKYMED PROGRAM IS:

- ✓ part of the National Space Plan (to supply remote sensing products and services for the monitoring and control and management of the risk relevant to Forest Fires, Floods, Landslides, Oil spills);
- ✓ developed under ASI responsibility in collaboration with the IT MOD;
- ✓ part of an IT/FR Agreement on “Earth Observation”, open to third parties participation.
- ✓ the Radar Component (metric and sub-metric capabilities) of the ORFEO “dual use” system including Radar and Optical Satellites;

The Cosmo-SkyMed Program, contributes to:

- ✓ finalize space technology products to applications
- ✓ promote and developing services of public interest
- ✓ develop an Italian role in the international service market
- ✓ increase the national scientific base aiming at the excellence of various disciplines
- ✓ foster Italian technological excellence and industrial competitiveness
- ✓ broaden and consolidate international cooperation
- ✓ support market development

COSMO-SkyMed Overall Architecture

□ System Elements:

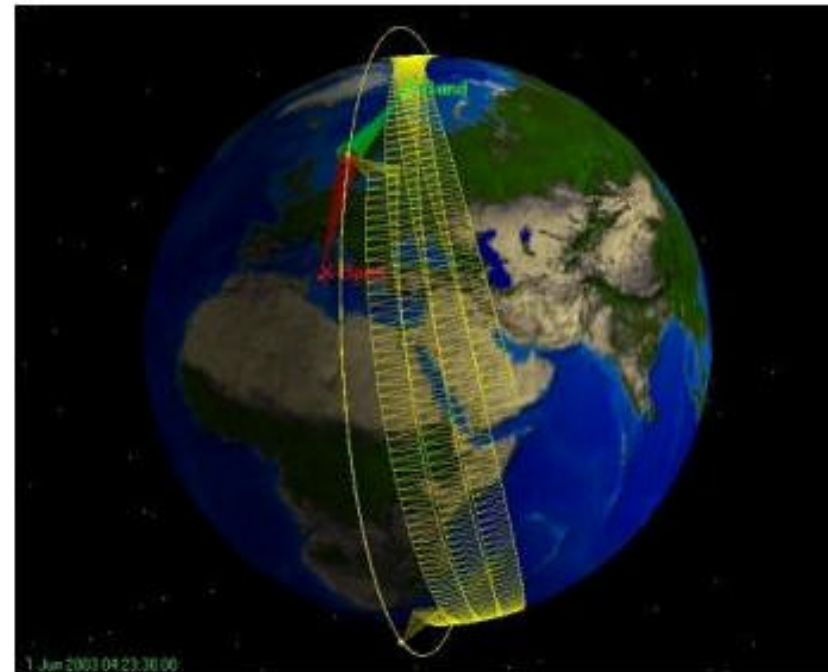
- A fully operational multi-satellite EO constellation with an imaging system based on advanced X Band RADAR technology, capable of acquiring very high resolution images from LEO.
- A fully operational ground infrastructure.

□ Dual Use:

- Dedicated Architecture
- Suitable procedures and accreditation

□ Deployment Strategy:

- Staggered delivery in orbit, with reasonable performance achieved as soon as the first satellite is operative, improved by successive launches:
 - ✓ flexible constellation build-up strategy;
 - ✓ graceful degradation of the nominal performance in case of satellite failure



COSMO-SkyMed Overall Performance

- **The System guarantees:**
 - **Very short response time to access any Earth location worldwide (<18/24 h)**
 - **Revisit times from 6 to 12 hours allowing multiple points of view (angles)**
 - **Priority (planning) and Security Management**
 - **Very accurate geo-location**
- **A variety of sizes and resolutions are available up to meter and sub-meter resolution products**
- **Up to 1800 images with such resolutions can be acquired each day with the full 4 X-Band SAR Satellites Constellation**
- **Each SAR Satellite is *agile* enough to acquire multiple images performing sensor re-pointing within a very short flight time**

COSMO - SkyMed GS Main Drivers

- **Dual Use**
- **Response time**
- **Expandability/Interoperability**
- **Availability / Operability**
- **Product Quality**



- **Security standards application**
- **Geographical distribution**
 - **Polar stations utilization**
 - **World wide GPS fiducial network**
 - **MAPS (mobile stations)**
- **Continuous calibration**
- **Modular architecture, with “plug and play” approach**
- **Functional and physical redundancy**
- **Use of TCP/IP protocols**
- **Integrated Logistics Support policies**
- **State of the art processing capabilities**

Dual Use Concept Implementation

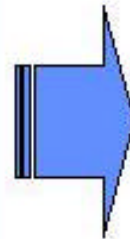
Main Dual Use main constraints:

1. Security

- Need To know
- Interconnection between Civilian and Military Domains

2. Operational

- Plan harmonization among Different class of users
- Priority policies
- Different Modes of operation



Through:

- **High planning automation (CPCM) with priority constraints**
- **Adoption of “secure decoupling techniques”**
 - Secure gateways
 - “Air gap”
 - Firewalls
 - Different crypto layers
- **Pre-planning capabilities**
- **Modes switching**
- **Approval of the tasking**

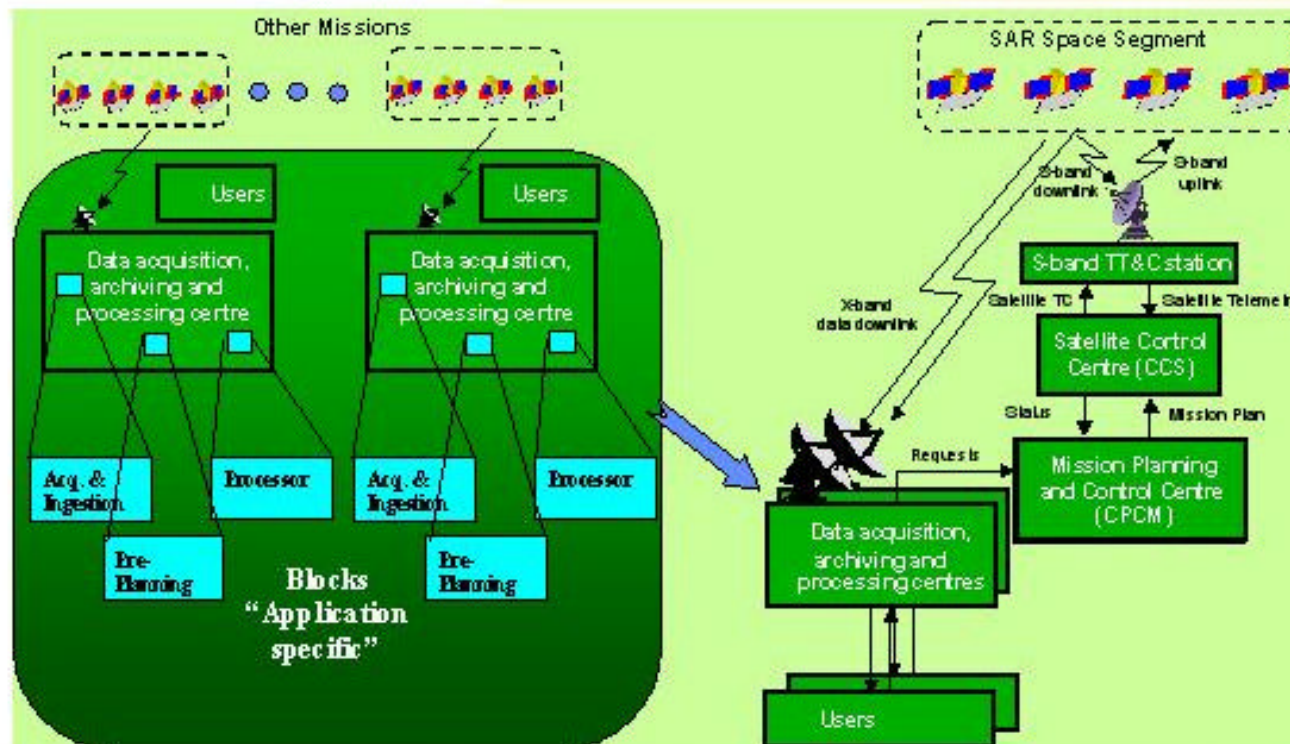
COSMO – SkyMed GS Interoperability & Expandability

Interoperability

- Adoption of international standards

Expandability, through plug-in of:

- Acquisition and ingestion chain
- Processors
- Pre-planning

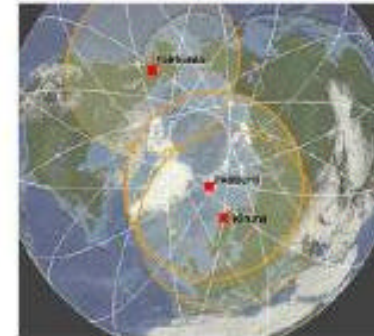


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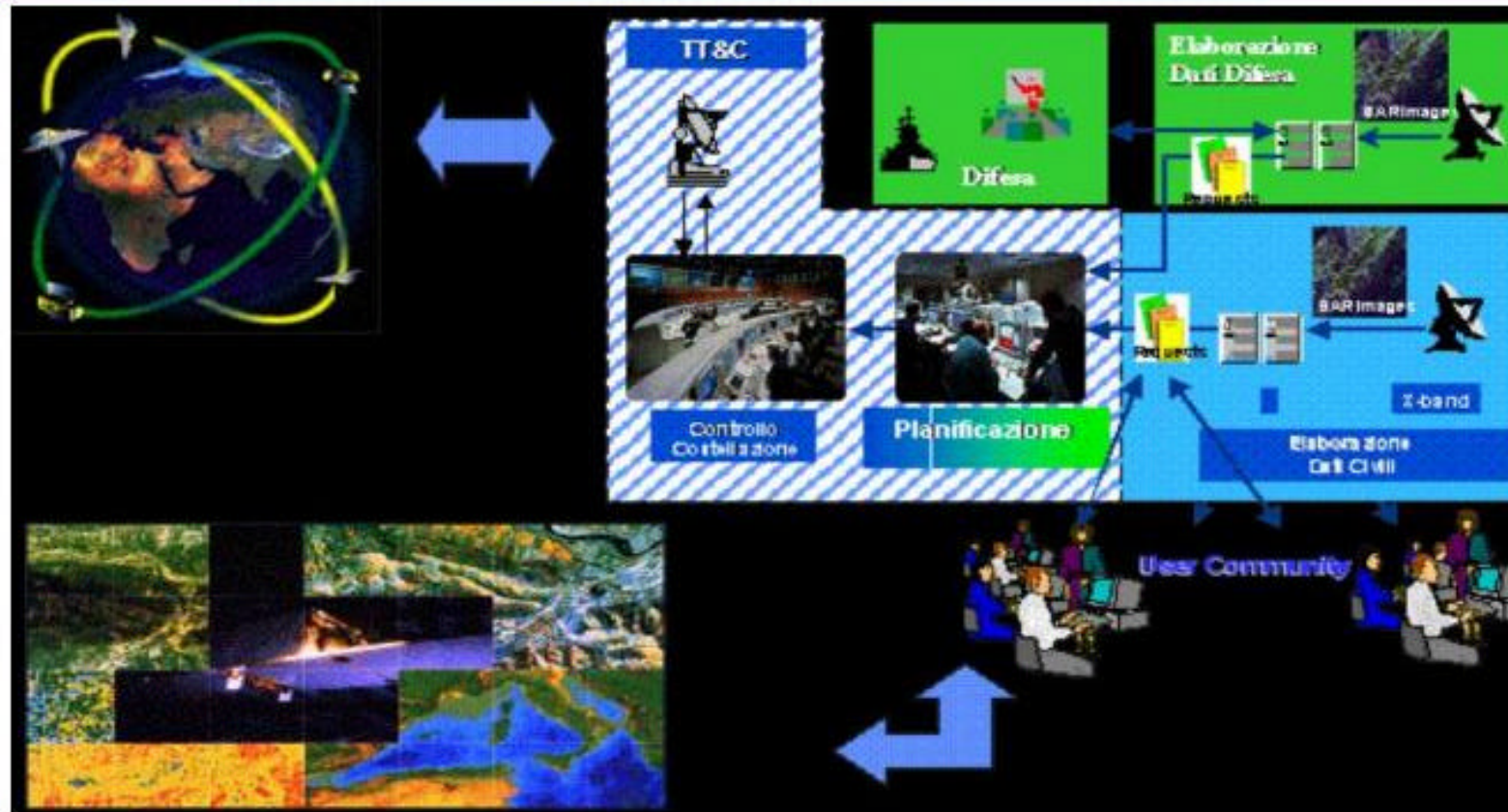
(Specific purpose COSMO-SkyMed).

COSMO – SkyMed GS Peculiar Elements

1. **CGS (Core Ground Segment) to acquire the raw data and to send TM/TC. This is a distributed infrastructure encompassing both National and polar stations**
2. **MAPS: associated to a CREDO, they are mobile units to be deployed in the crisis area,**
3. **Cataloguing/Archiving/Dissemination**



COSMO-SkyMed Overall Architecture



The Overall Architecture is fully compliant to the Mission Requirements

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SAR Standard & Higher Level products

❑ SAR Standard Products

- RAW
- SCS (Single look, Complex, Slant range)
- DGM (Detected, Ground range, Multilooked)
- GEC-GTC (Geocoded)

❑ Auxiliary (Orbital) Products

- Predicted
- Filtered
- Restituted

❑ Higher Level SAR Products

- DEM and Interferometric products
- Quick look
- Speckle Filtered
- Coregistered
- Backscattering
- Mosaicking

SAR Standard Products

The COSMO SKYMED SAR standard products are:

<input type="checkbox"/> RAW	Level 0	Received SAR echo signal
<input type="checkbox"/> SCS	Level 1A	Single look, Complex, Slant range
<input type="checkbox"/> DGM	Level 1B	Detected, Ground projected, Multilooked
<input type="checkbox"/> GEC	Level 1C	Geocoded Ellipsoid Corrected
<input type="checkbox"/> GTC	Level 1D	Geocoded Terrain Corrected

Each item corresponds to many possible product types depending on the different sensor acquisition modes:

- Stripmap: medium resolution, medium swath (ERS, XSAR SRL1/2)
- Polarimetric: medium resolution, medium swath (SIRC, Envisat)
- ScanSAR: low resolution, large swath (Radarsat, Envisat)
- Spotlight: high resolution, small swath (no operational sensors)

Standard products description

- ❑ RAW
 - Generation of higher level products (SCS)
 - SAR Technology Research
- ❑ SCS
 - It is a complex image whose modulus codes the scene reflectivity at the radar wavelength and the phase codes the satellite target distance (useful for interferometry)
 - The product is in radar geometry i.e. side looking (slant range) hence there are great geometric deformations
- ❑ DGM
 - It is a image whose values code the scene reflectivity at the radar wavelength
 - the product is in radar geometry but projected on ground i.e. ground range-azimuth
- ❑ GEC & GTC
 - They correspond to classes of products rather a couple of products since the image contains the same input data physical quantity (is not restricted only to scene reflectivity)
 - geocoding processing requires that input data comes with ancillary data needed to geolocate pixel (e.g. timing, orbit)

Standard products volume

Product	Mode	Submode	Product size [Mb]	Comment
SCS	Stripmap	Himage	1100 ÷ 1800	
		PingPong	184 ÷ 265	One file per polarization
	ScanSAR	WideRegion	1100 ÷ 1350	Az mosaicked and undersampled
		HugeRegion	350 ÷ 400	
	Spotlight	Spotlight 2	530 ÷ 700	
DGM	Stripmap	Himage	510 ÷ 616	2 x 2 looks
		PingPong	75 ÷ 109	1 x 2 looks, One file per polarization
	ScanSAR	WideRegion	330 ÷ 450	3 x 1 looks
		HugeRegion	83 ÷ 105	3 x 2 looks
	Spotlight	Spotlight 2	923	1 look
GEC & GTC	Stripmap	Himage	1000 ÷ 1250	
		PingPong	150 ÷ 220	One file per polarization
	ScanSAR	WideRegion	675 ÷ 900	
		HugeRegion	167 ÷ 210	
	Spotlight	Spotlight 2	1850	

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Standard product media format

- ❑ Guidelines for format definition (still in progress) are:
 - the capability to include multi-layer images with a set of annexed ancillary information
 - the capability to be ingested by common commercial tools for image processing

- ❑ Candidate solutions are:
 - TIFF
 - HDF5
 - HTML
 - CEOS

- ❑ Specific formats oriented to military usage:
 - STANAG

Auxiliary Products

□ Orbit types:

- **Restituted:** estimated over a time interval using the GPS tracking data (ground- and space-based) acquired in that interval integrated with the ancillary data (GPS constellation orbits, Earth Orientation parameters, Solar and Geomagnetic Flux values) and using the most updated models available at the time of data reduction.
- **Filtered:** properly smoothing the CSK LEO on-board navigation state vectors as available.
- **Predicted:** over temporal arc in which Earth tracking data are not available. The orbit is obtained by propagating an estimated state vector

□ GPS Fiducial Network:

- In order to allow COSMO-SKYMED to be autonomous from IGS (at maximum possible extent) and also to overcome the time lag in in the IGS ground data delivery, the development of a a worldwide GPS Fiducial Network composed by ≈ 20 stations is foreseen in the project

Higher Level products

□ DEM

- can be generated with 2 classes of methods:
 - ✓ Interferometry (SAR), automatic processing
 - ✓ Radargrammetry (SAR), manual processing
- processing chain includes the generation of two Interferometric products: wrapped flattened phase and terrain corrected coherence

□ Quicklook

- generated with low resolution focusing of SAR RAW data or by spatial averaging the full resolution products, even non SAR
- has a lat,lon grid overlaid for easy retrieval of geolocation info, optionally (roughly) georeferenced and radiometry stretched to 8 bit

□ Speckle filtered

- radar reflectance data but with a lower level of speckle noise
- image features contours and strong scatters are preserved by adaptive filtering algorithms

Higher Level products

❑ Coregistered

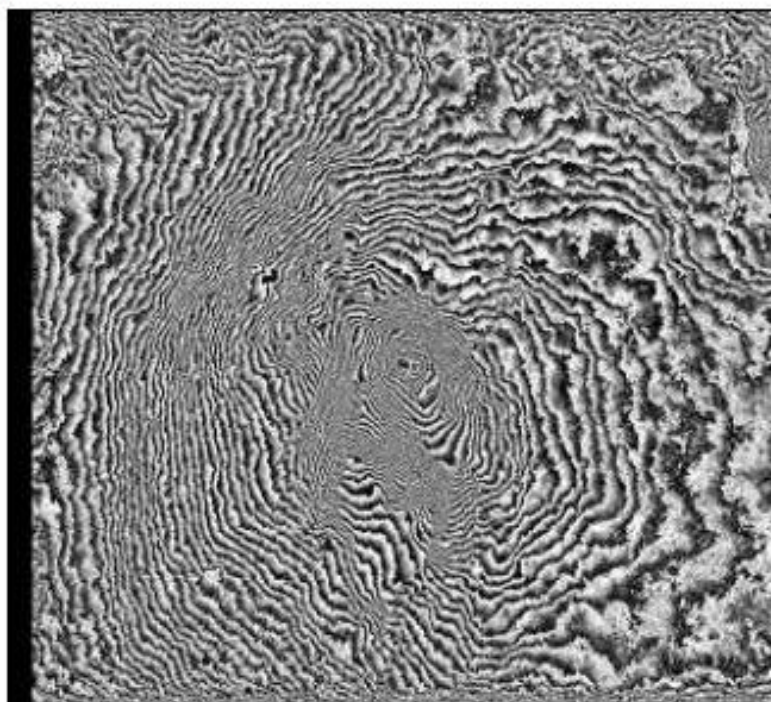
- stack of a set of coregistered reflectance data layers obtained from: SAR with SAR sharing the same geometry or Optical with Optical having similar incidence angle or Geocoded SAR with Geocoded Optical
- processing is automatic in all modes of operation

❑ Backscattering

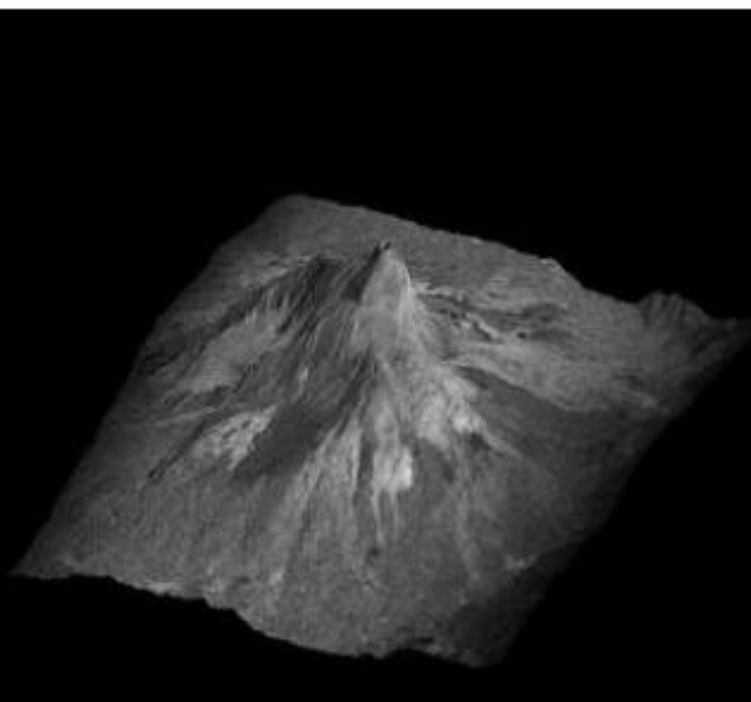
- RCS, Radar Cross Section of the scene, retrieved using SCS or DGM or Geocoded images and support data (calibration constant, DEM)

❑ Mosaiked

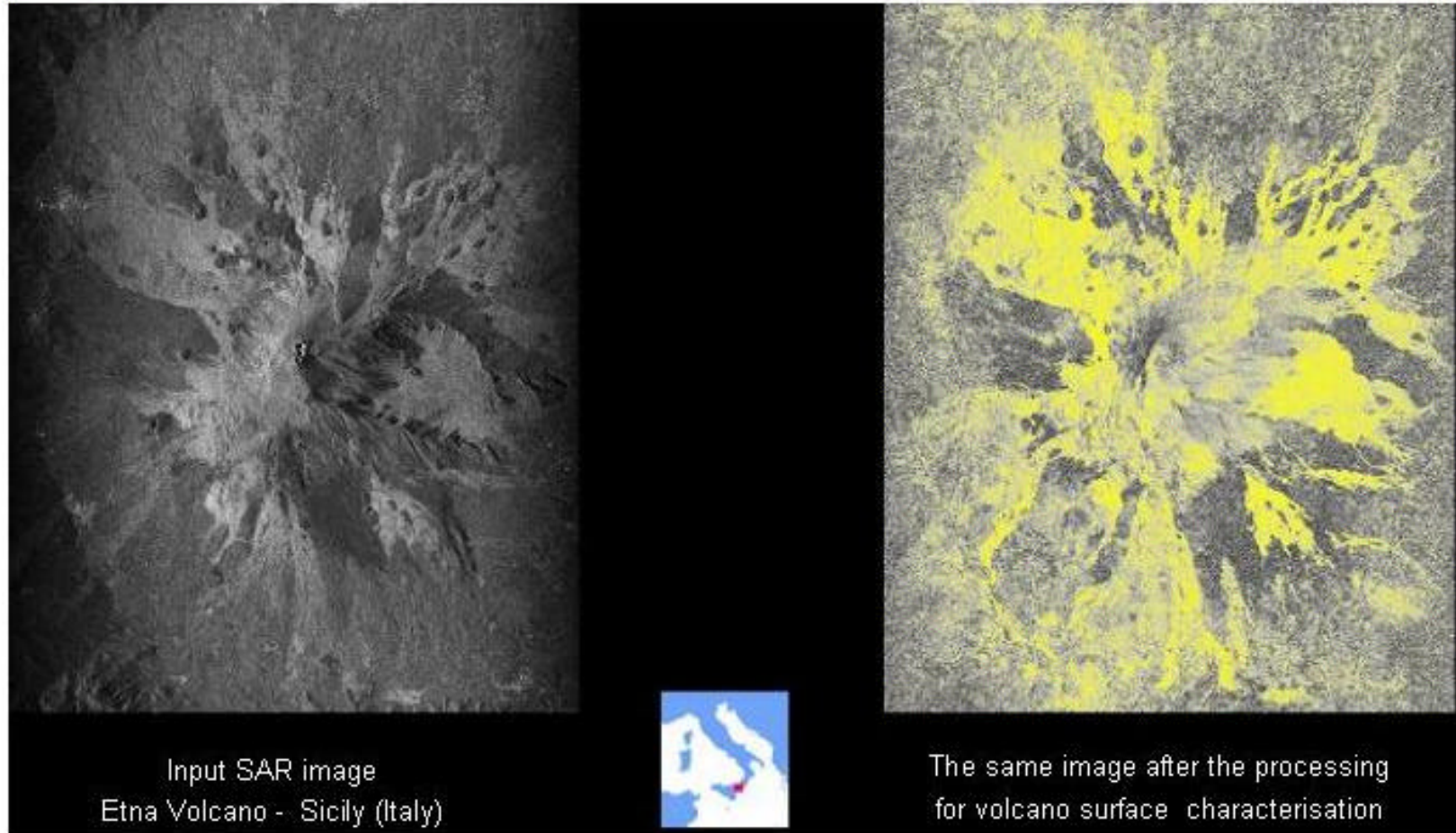
- input data is constituted by a set of geocoded images all sharing the same cartographic projection and all containing same physical quantity
- support data is constituted by the error map used to weight images in overlapping zones
- equalization of input images radiometry can be applied to minimize differences in the various regions of the mosaic, when aspect (rather radiometric accuracy) is important



SAR Interferogram
Etna Volcano - Sicily (Italy)



SAR DEM
Etna Volcano - Sicily (Italy)

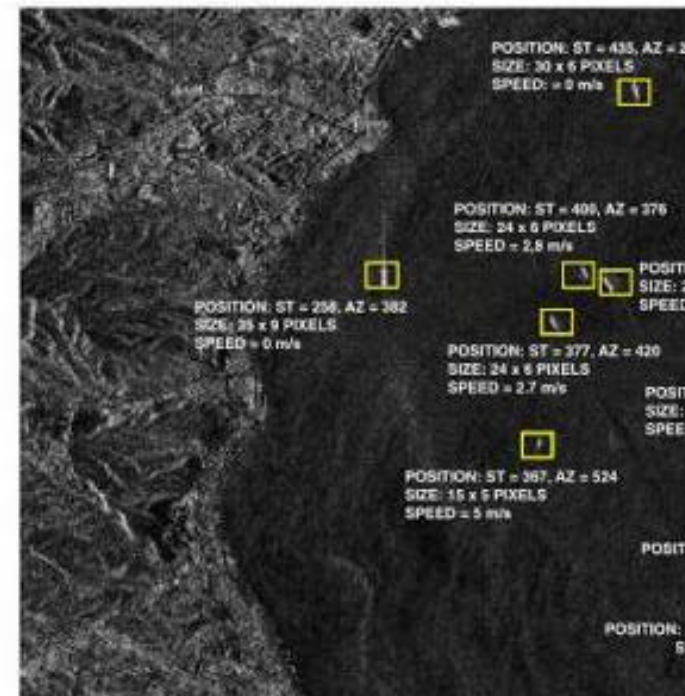


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Input SAR image
Messina Strait of Sicily (Italy)

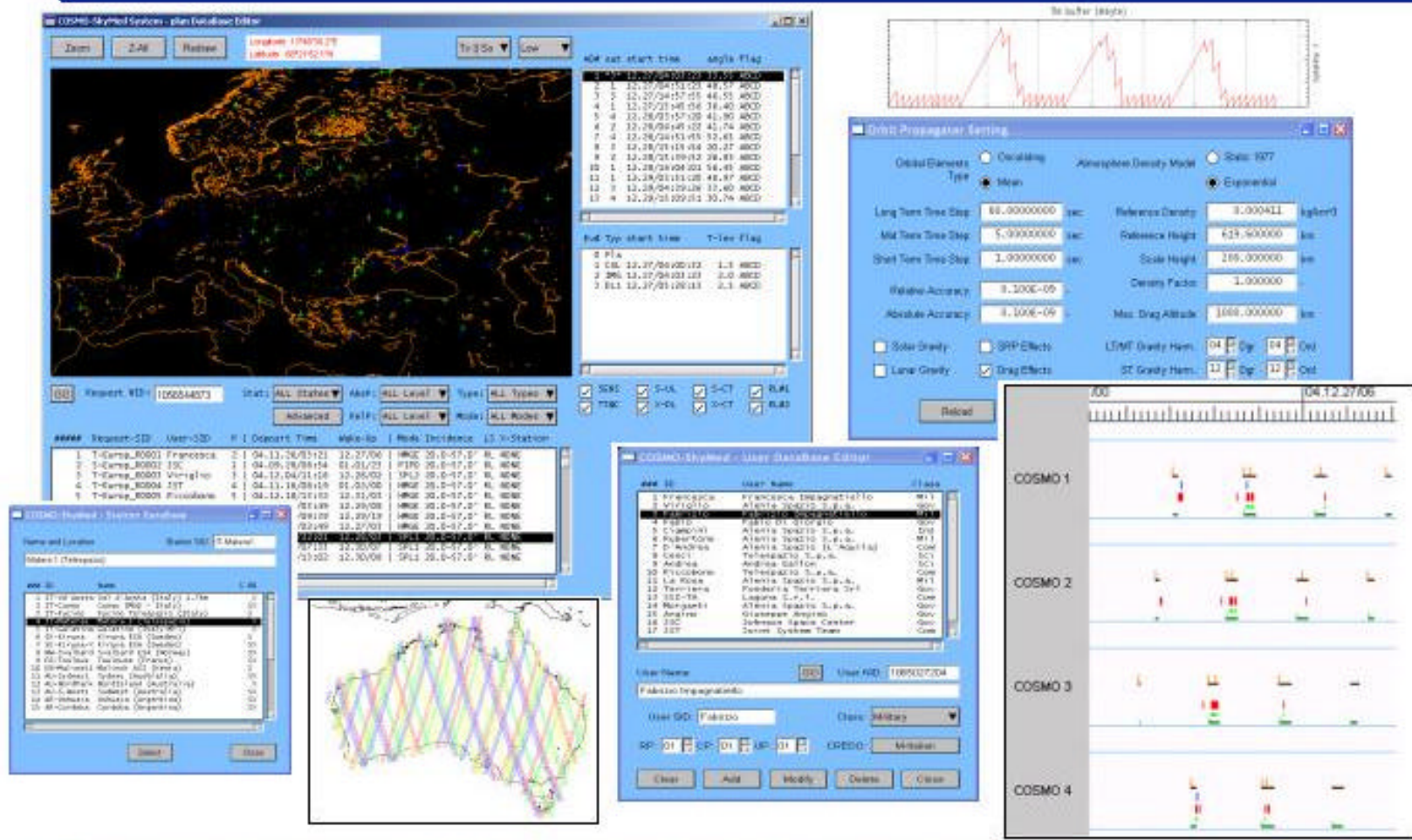


The same image after the a
processing for target detecti
motion characterisation

COSMO – SkyMed Mission Simulator

- A specific mission simulator tool has been conceived and developed in order to:
 - ✓ take properly in account all functional and operational characteristics of the system.
 - ✓ provide a key support to define and detail priority and confidentiality rules, as well as the algorithms and the ties needed for the generation of mission plans which respect the requirements and the priorities and that minimise the impact on the commercial operability of the system.

COSMO – SkyMed Mission Simulator



The screenshot displays the COSMO-SkyMed Mission Simulator interface, which includes several key components:

- Main Dashboard:** Features a satellite imagery view on the left, a central data table for mission parameters, and a right-side control panel for orbit propagation settings.
- Orbit Propagation Settings:** A detailed panel on the right with options for 'Orbit Elements Type' (Circular, Mean, Expanded), 'Atmosphere Density Model' (Scale 107, Expanded), and various time step and accuracy parameters.
- Data Tables:** Multiple tables listing mission details such as 'Mission ID', 'User ID', 'Start Time', 'End Time', and 'Status'. One table lists mission IDs 1 through 5, and another lists user names and IDs.
- Graphs:** A line graph at the top right shows a signal waveform over time.
- Maps:** A map at the bottom center shows the orbital paths of multiple satellites over a geographic area.
- Control Panels:** Includes a 'User Database Editor' at the bottom center for managing user profiles and a 'Status' panel on the right showing the operational status of four COSMO satellites.

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Program Status and Key Events

PREVIOUS STEPS:

- End of Phase B1 1998
- Design and Bread boarding - Phase B2 1999
- Critical technological development 1998/2002

⇒ **Currently the Satellite is under qualification**

NEXT:

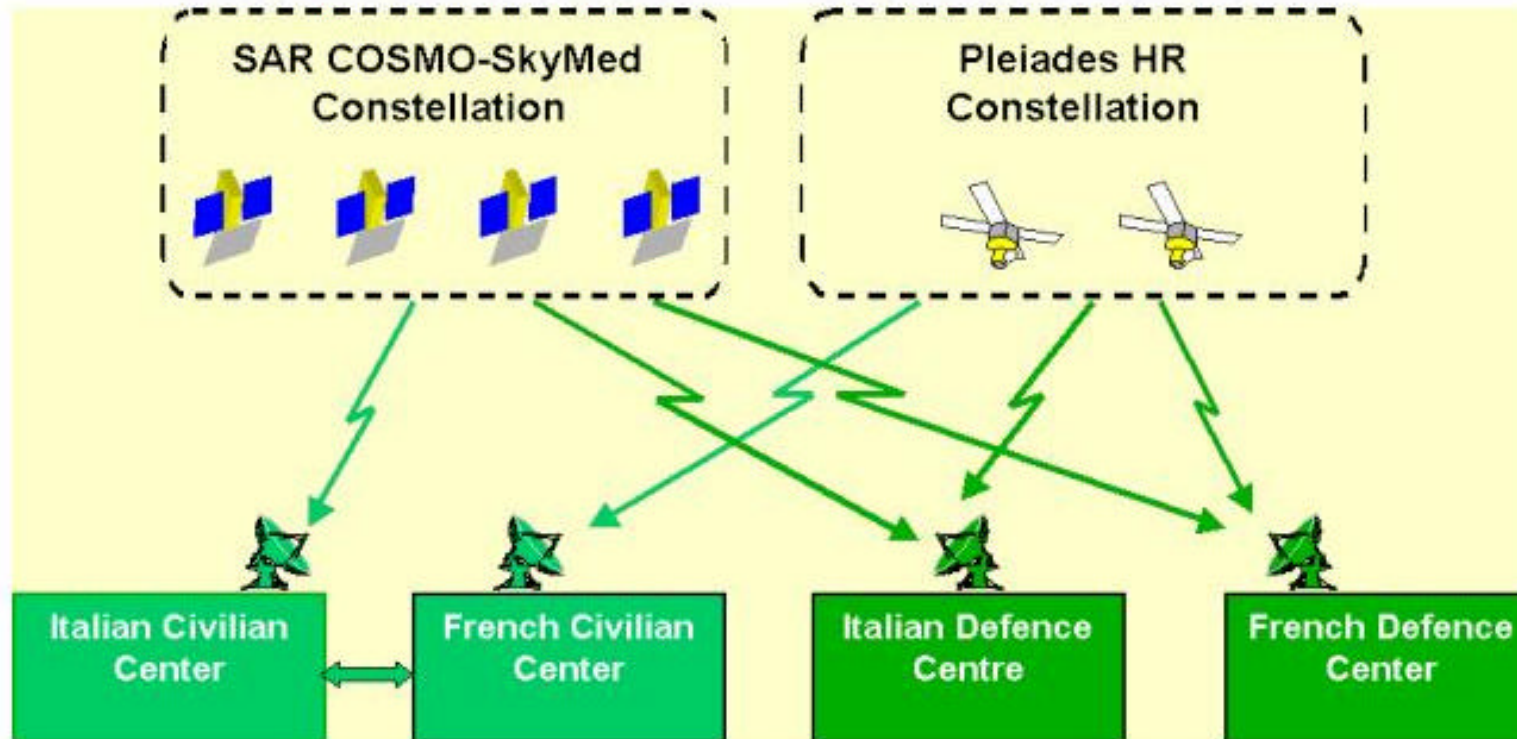
- Development - First sat. 2000/2003
- Launch of the first satellite mid 2005
- Constellation completion mid 2007

❑ ORFEO stands for:

- Optic and Radar Federated Earth Observation system

❑ ORFEO is:

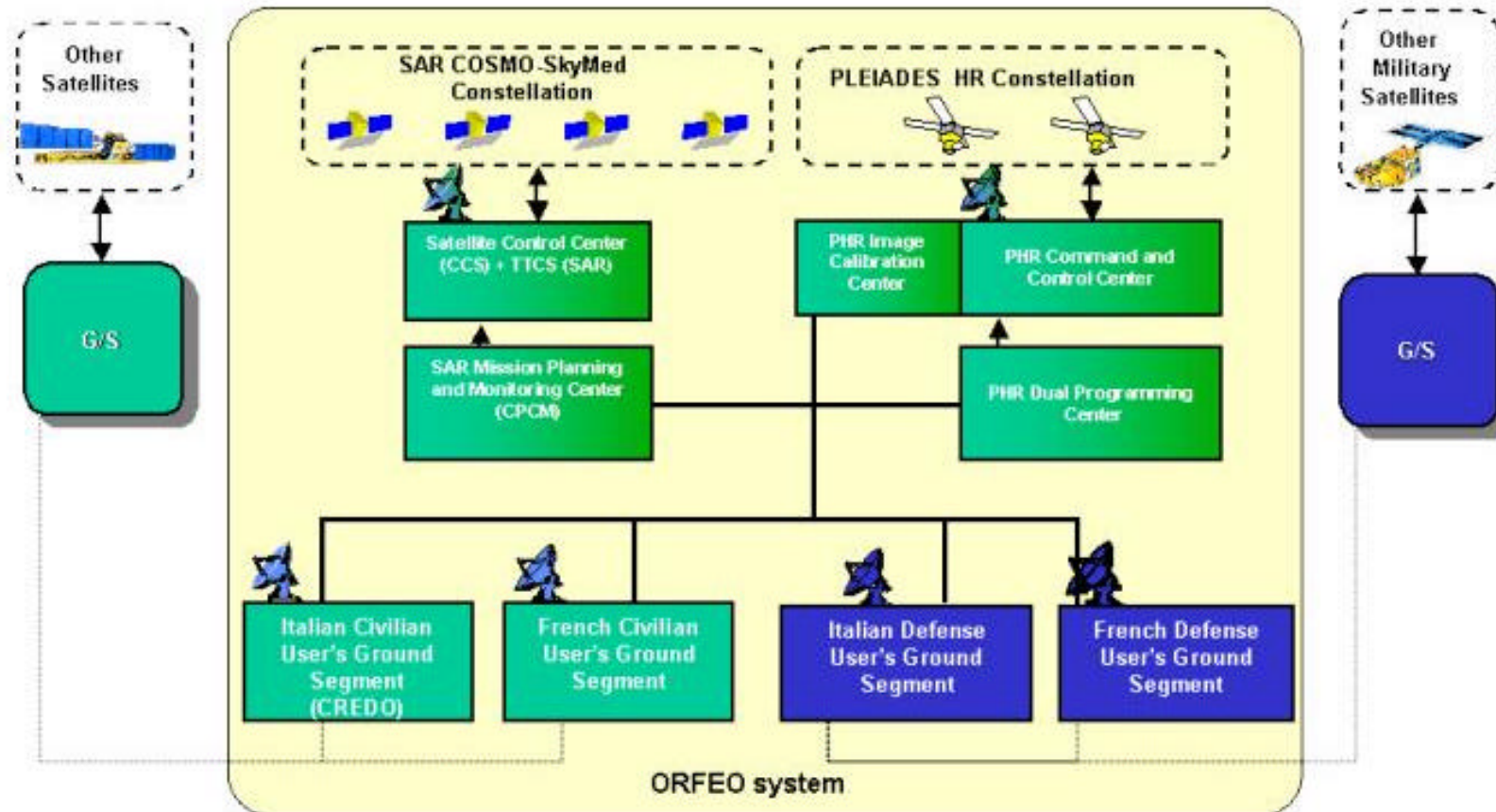
- Dual: it offers services to Defense and civilian users,
- Multi-sensors:
 - ❖ it includes two components:
 - COSMO-SkyMed SAR (CSK)
 - Pléiades HR Optic (PHR)
 - ❖ it allows the users to see a federated system, users can:
 - deposit multi-sensor requests simultaneously on CSK and PHR components (mixed, coupled ...)
 - Browse a meta-catalog,
 - Receive PHR and SAR products
- International: the cooperation is between France and Italy. The MoA foresees entry of new partners.



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ORFEO system overview



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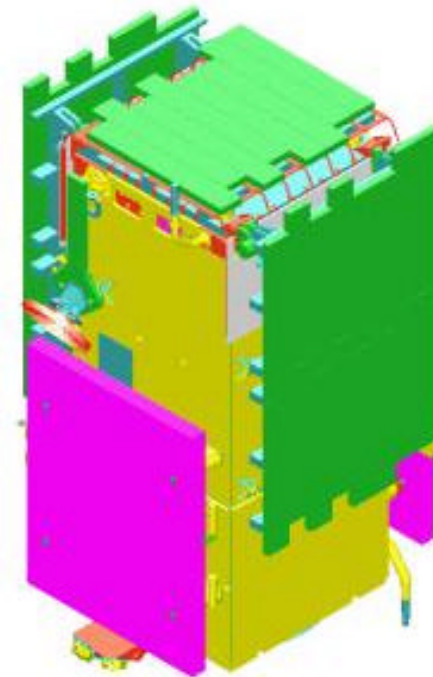
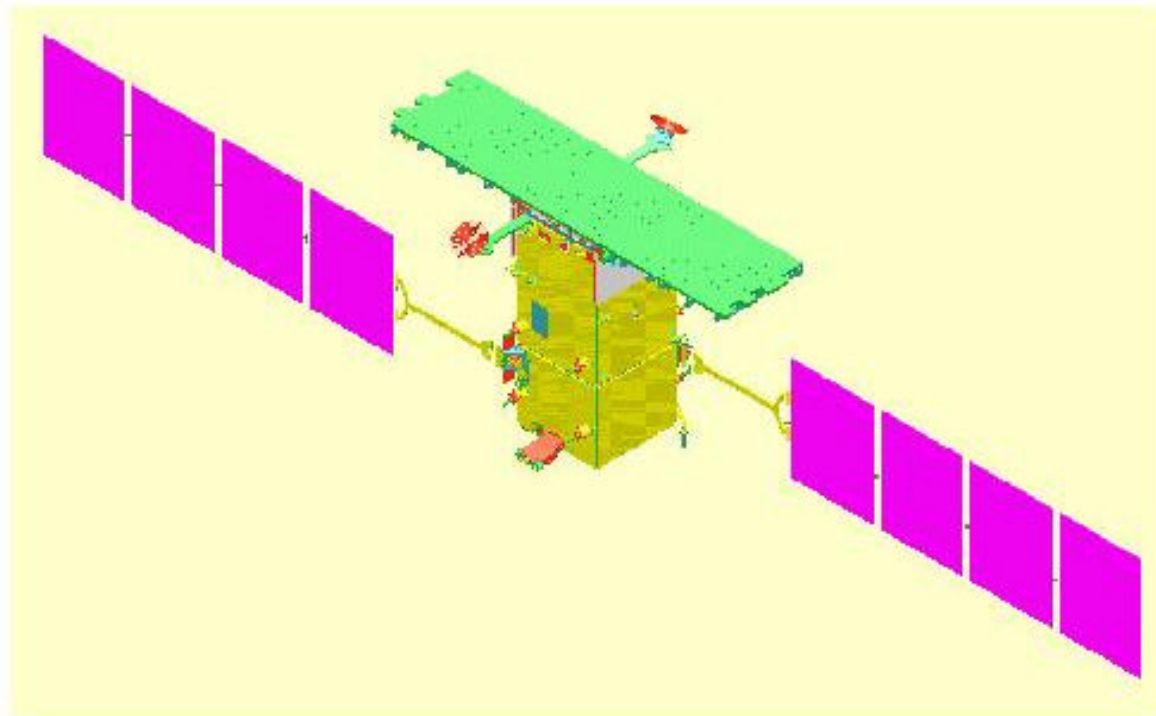
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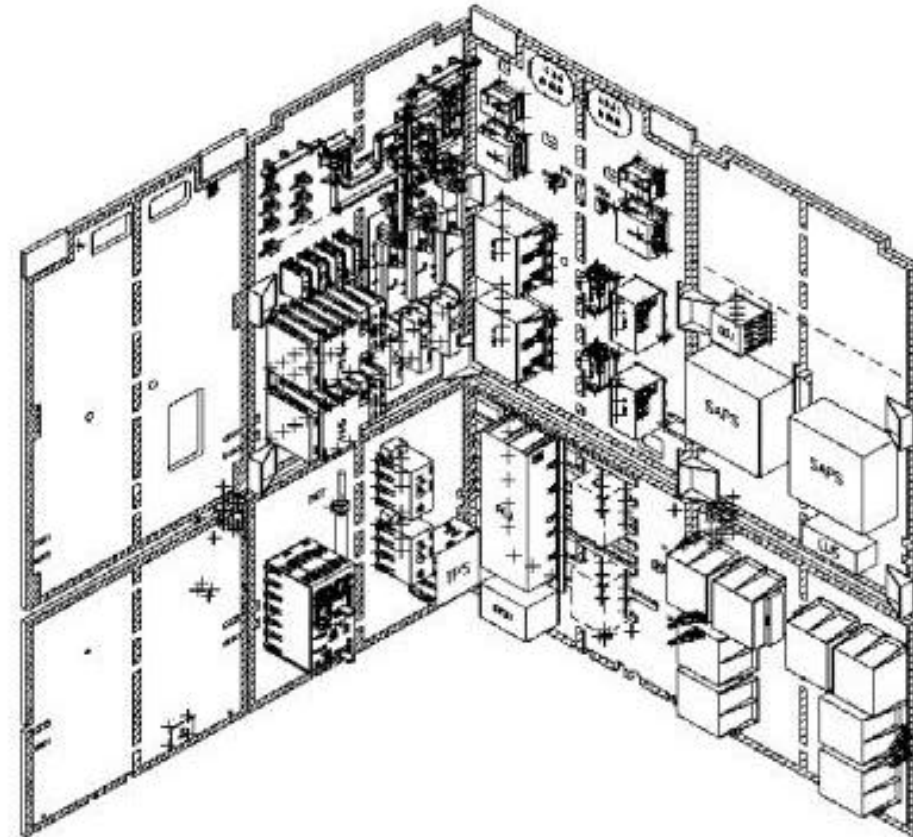
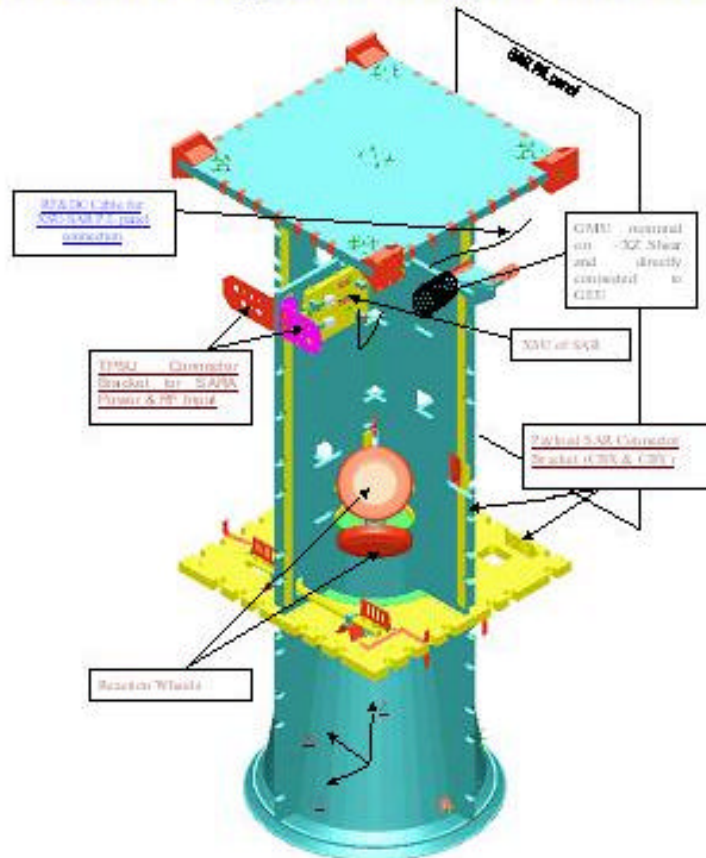
COSMO-SkyMed Satellite in deployed and stowed configuration



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COSMO-SkyMed Satellite internal layout



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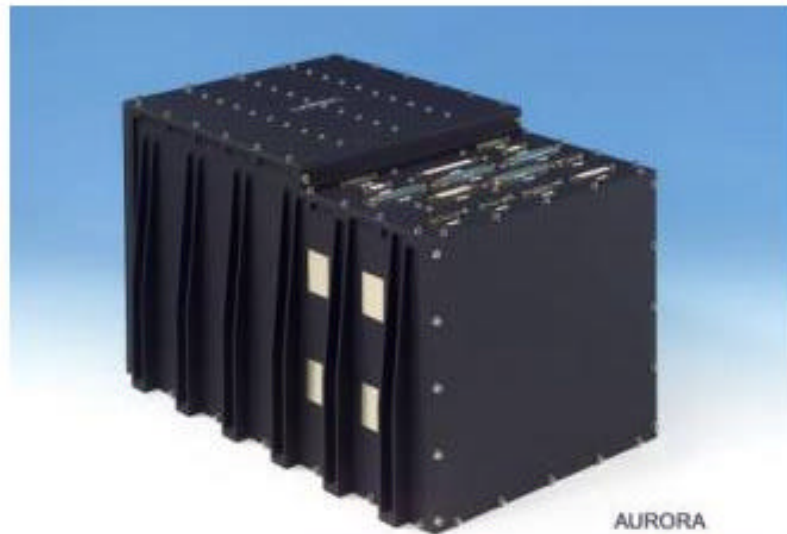
COSMO-SkyMed System - Space Segment



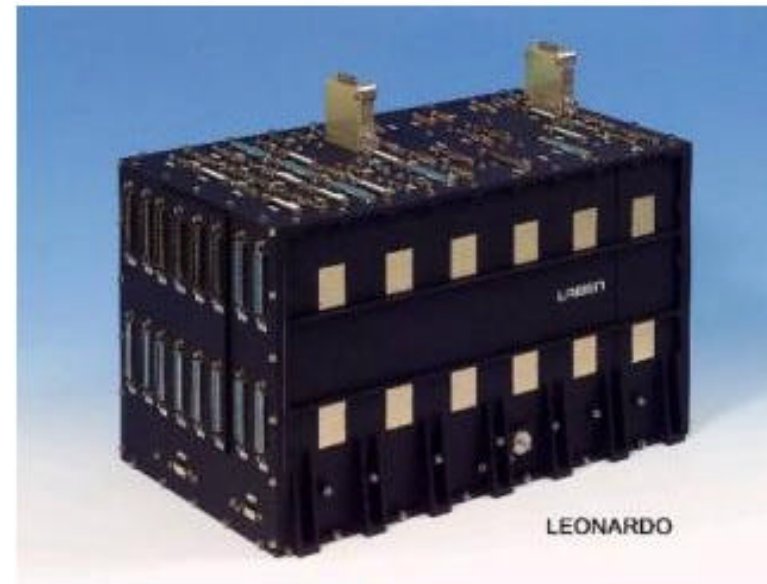
Structural Model

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Mass Memory



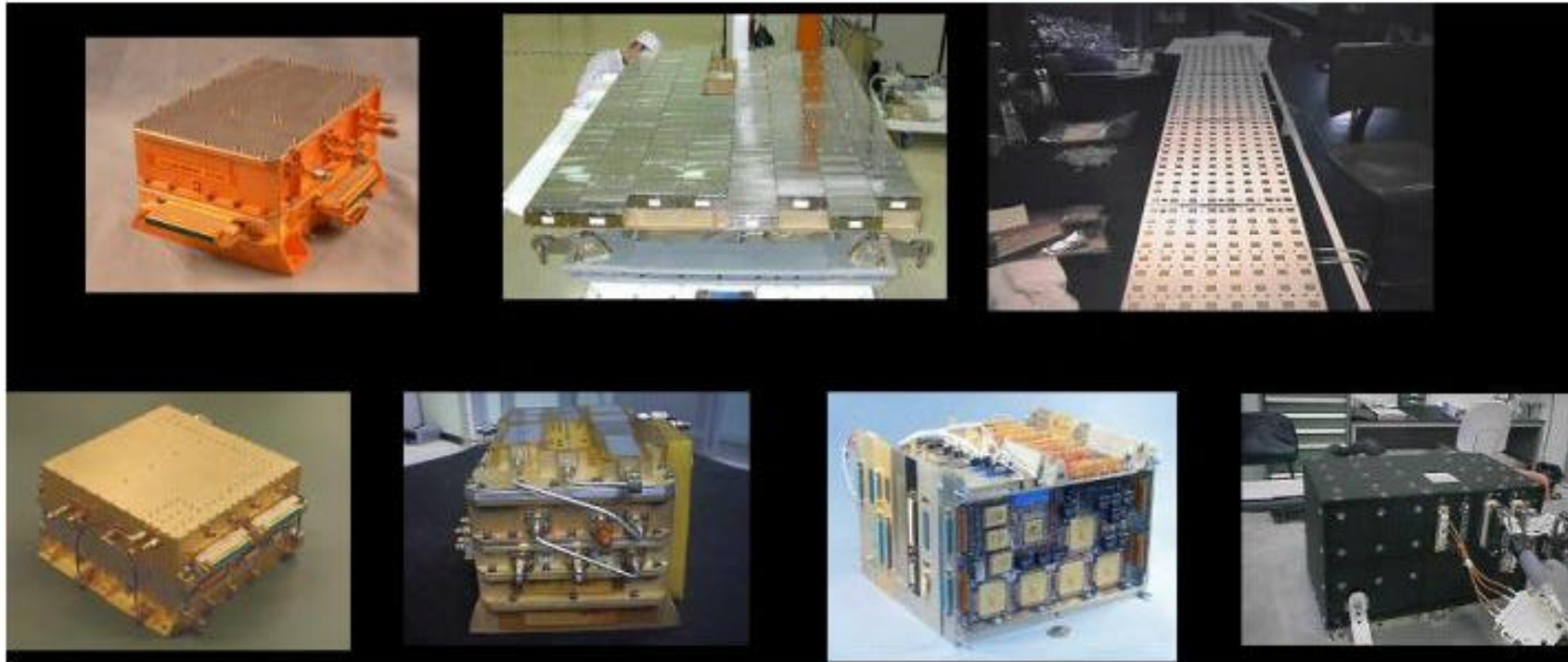
S/L Computer

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COSMO-SkyMed System - Space Segment

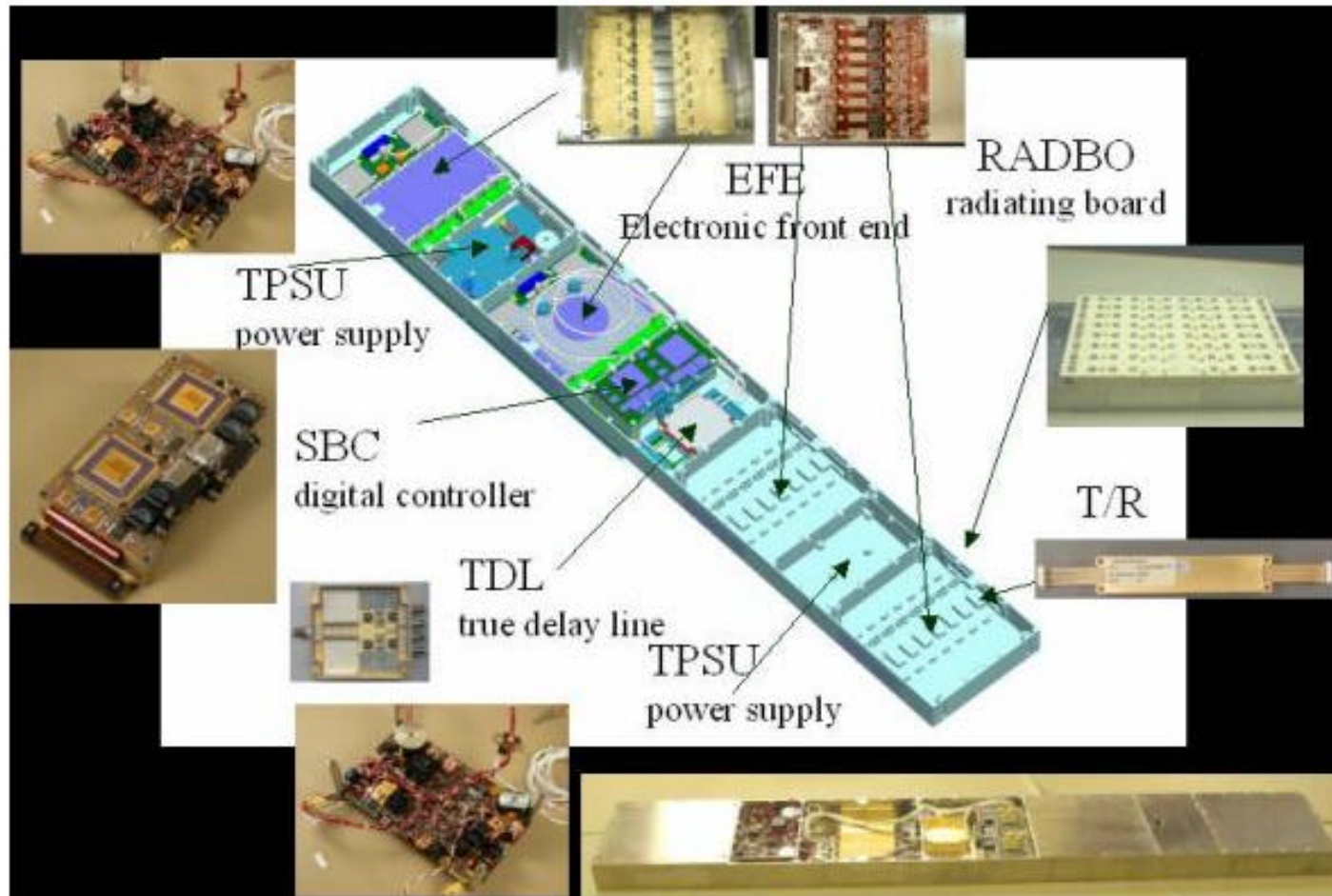
Antenna Developments



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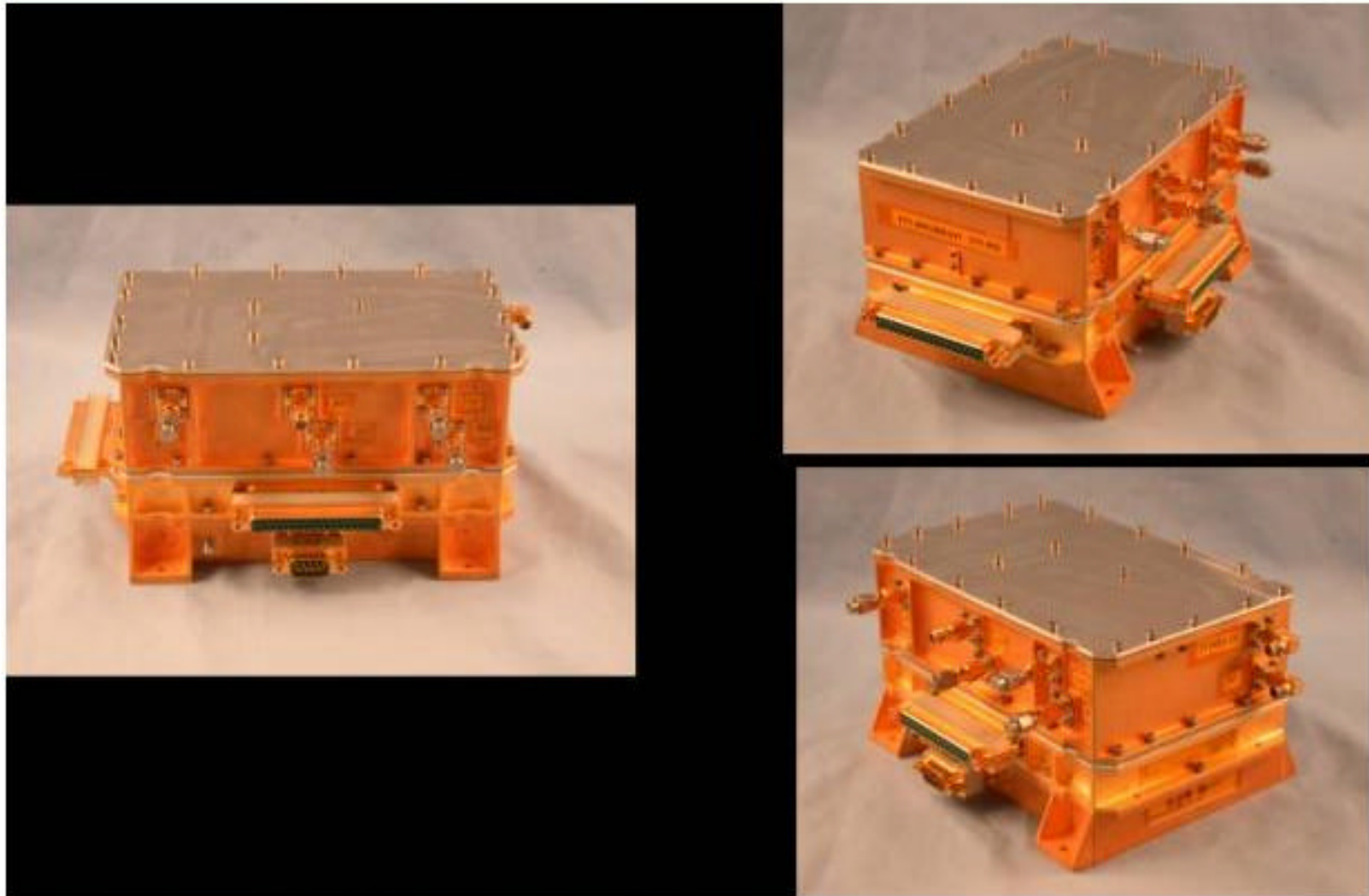
Tile



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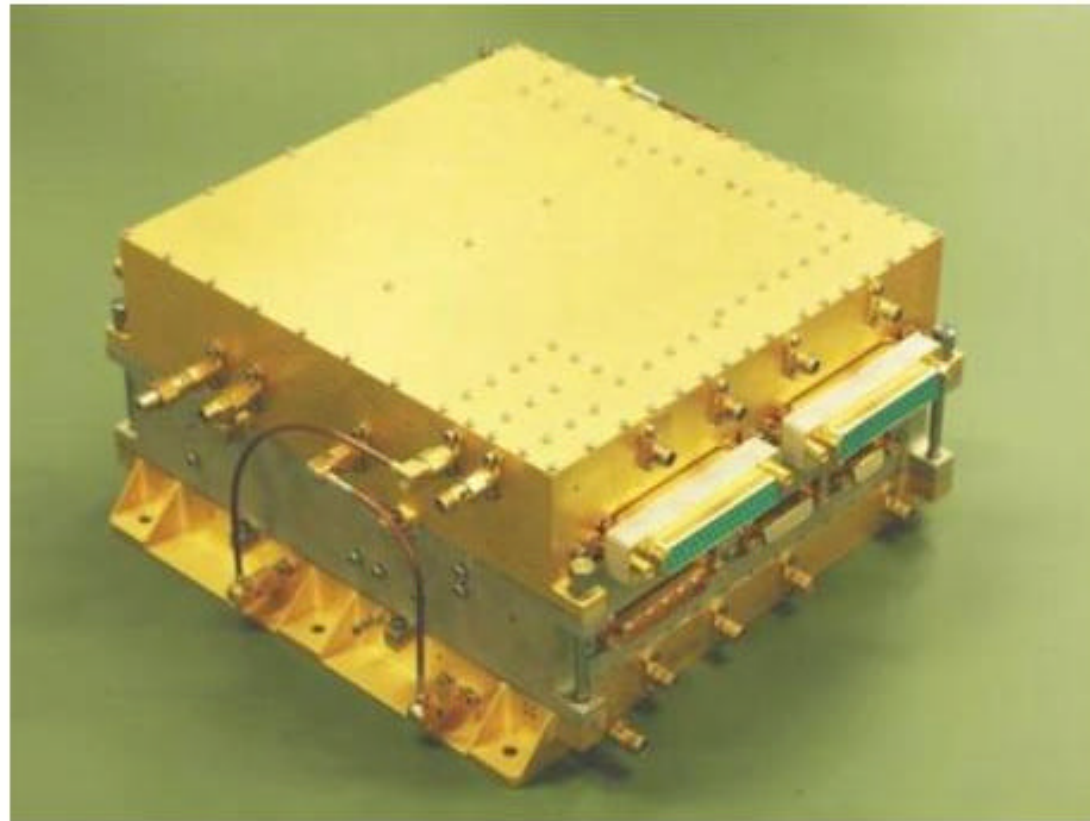
Frequency Generator



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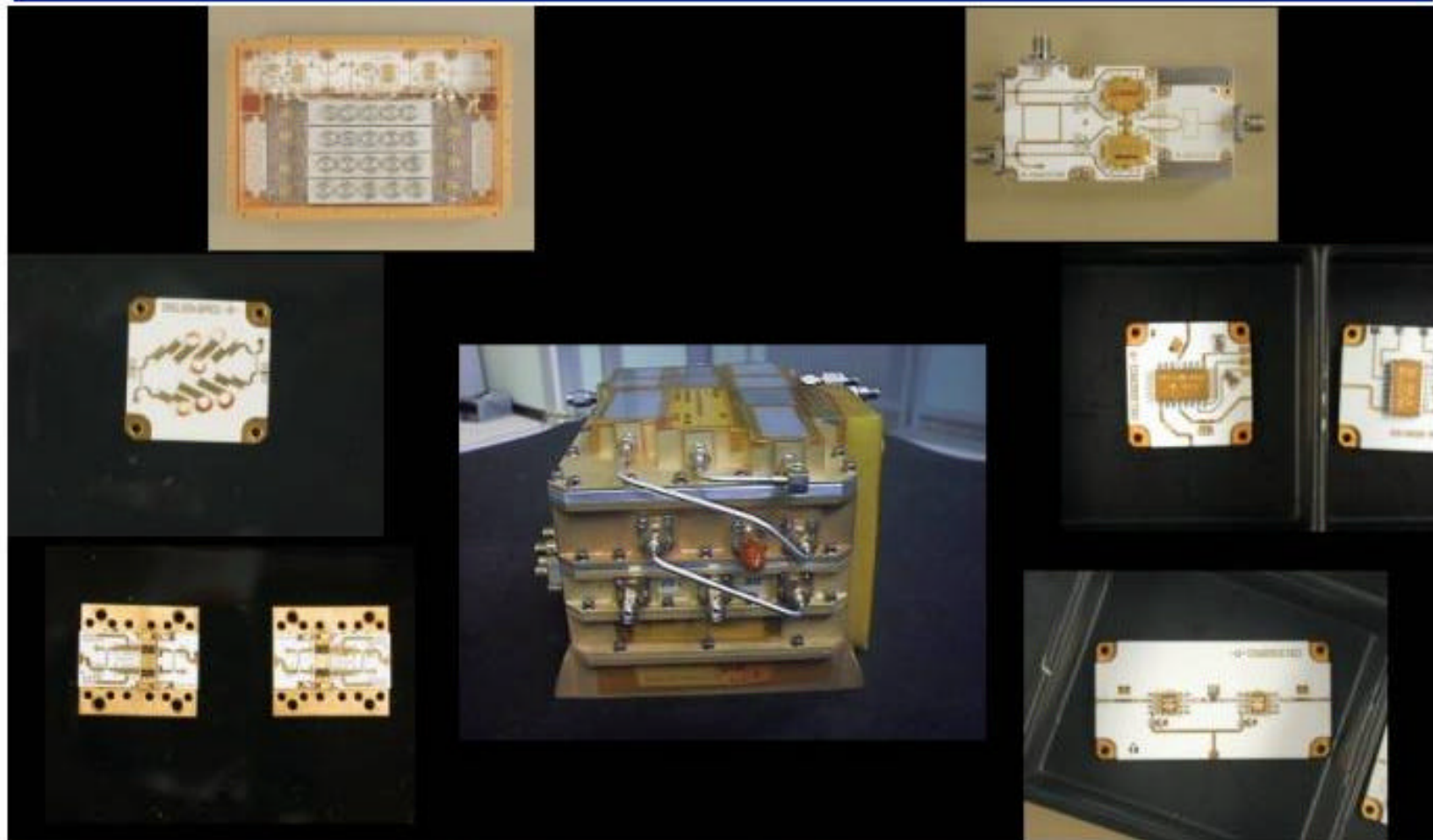
X-band Drive Unit (EQM)



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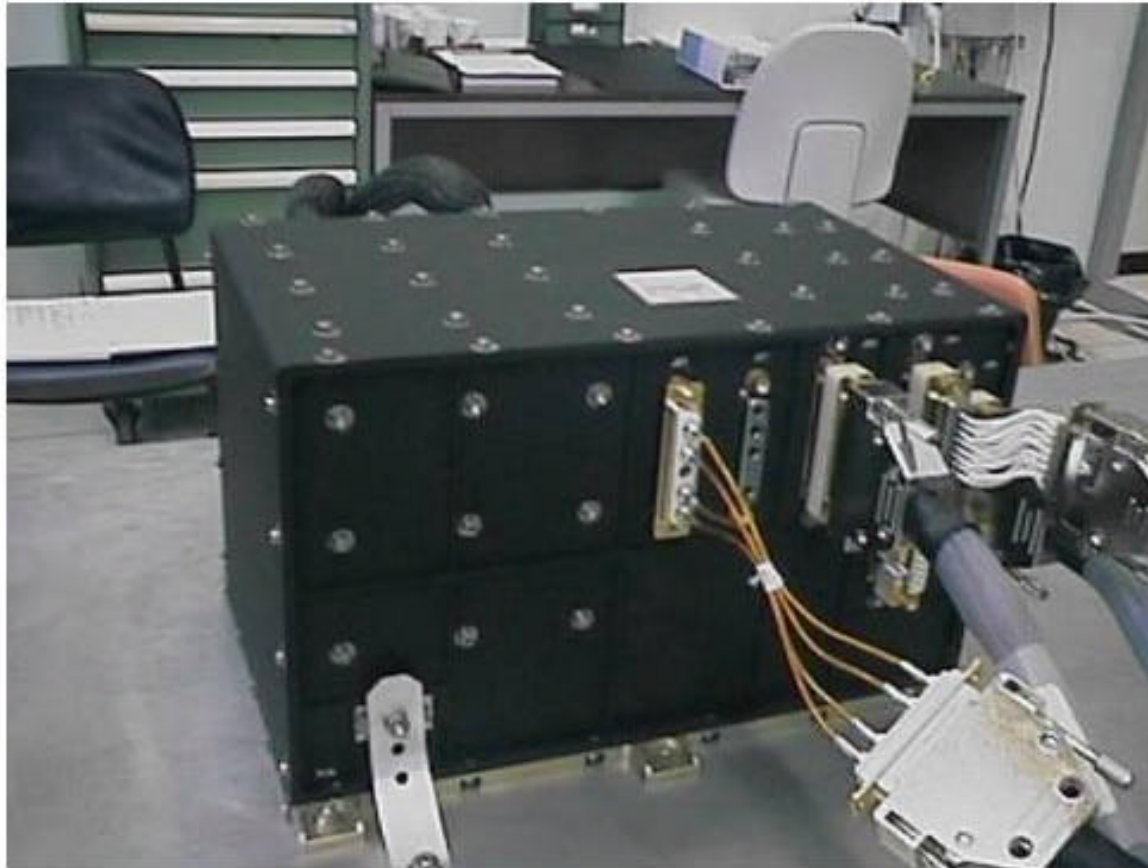
Down Converter Unit



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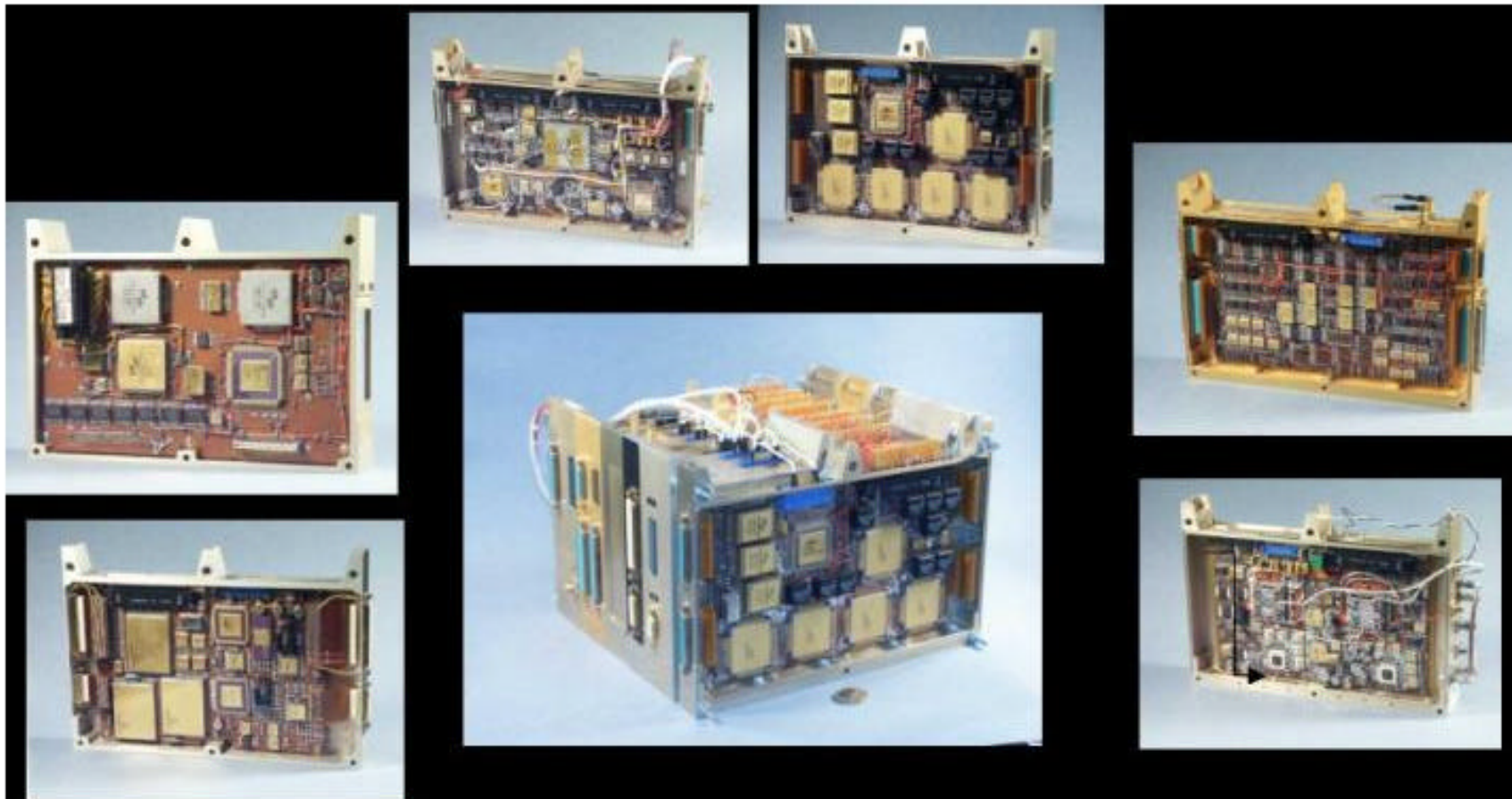
(Specific purpose COSMO-SkyMed).

Central Power Supply (CPSU)



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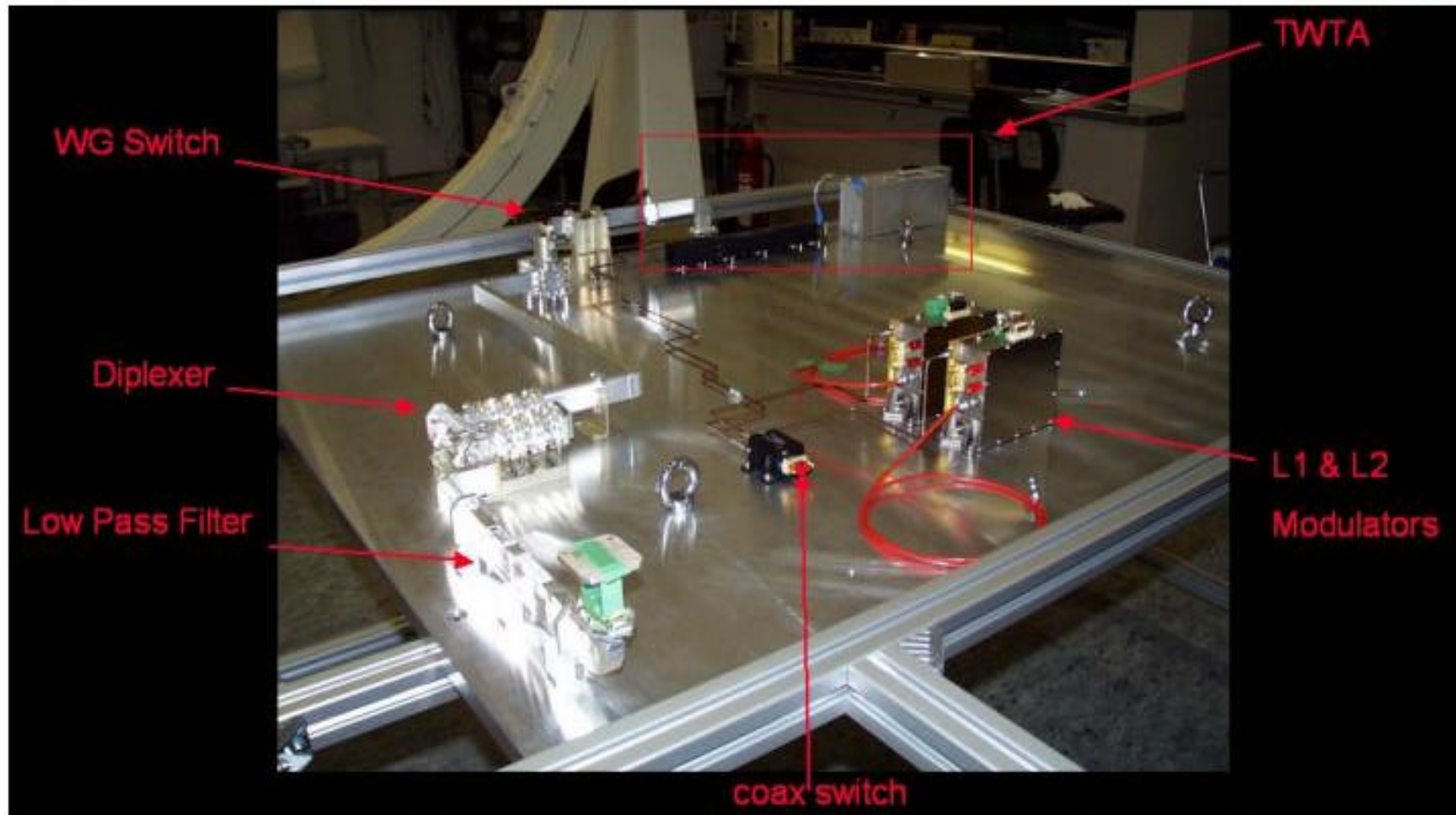
(Specific purpose COSMO-SkyMed).



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TXA Architecture - EM



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(Specific purpose COSMO-SkyMed).



- Extremely wide rotational symmetrical coverage $\theta_c = 65.3$ deg (half cone).
- Isoflux-shaped gain mask, according to the different path lengths Vs angle, with a maximum value of 5.5 dBi at 65.3°



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(Specific purpose COSMO-SkyMed).